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The Soviet T-72 Tank Performance

CIA HISTORICAL REVIEW PROGRAM
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An Intelligence Assessment

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SW 82-10067X
August 1982

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The Soviet T-72 Tank Performance

An Intelligence Assessment

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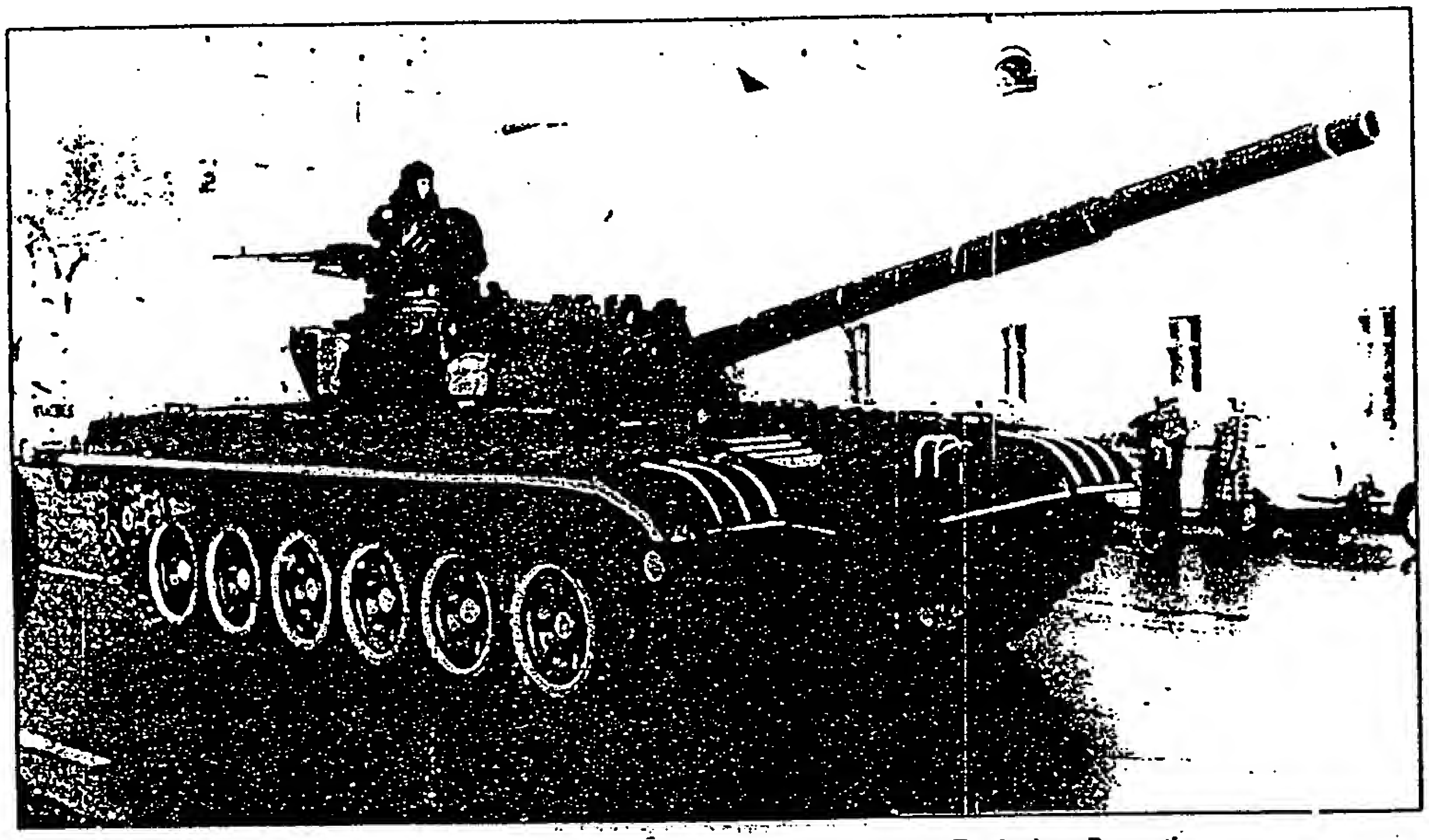
Figure 1

The Soviet T-72 Tank



Mobility	
Weight	41 mt
Power	780-HP, V-12 diesel
Top speed	60 km/hr

Firepower	
Main gun	125 mm
Coaxial machinegun	7.62 mm
Dual-purpose machinegun	12.7 mm

Equivalent Protection

[ ]

[ ]

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The Soviet T-72 Tank Performance

Key Judgments

The Soviet T-72 tank (figure 1) is a formidable weapon system

The 125-millimeter (mm) cannon of the T-72 fires kinetic-energy (KE) rounds at a muzzle velocity of 1,800 meters per second, which is several hundred meters per second higher than the muzzle velocity of Western guns

In determining the degree of protection provided by the armor on the T-72, we have used the accepted standard of head-on engagements on level terrain.

Our judgments on the protection provided in the T-72 are based primarily on two factors—our estimates of the design of and the material used in the armor and

Information available as of 9 July 1982 has been used in the preparation of this paper.

We have limited information on the destruction of the [redacted] T-72s in [redacted] by the Israeli forces. [redacted] these tanks were penetrated on the sides or through the top where the armor protection is less than on the front. Nevertheless, the Soviets guaranteed in 1979 or 1980 that the T-72 can stop, over its 60-degree frontal arc, all fielded 105-mm KE munitions at ranges greater than 500 meters and can defeat the TOW and DRAGON missile warheads at any range. We believe these statements to have been true at that time.

The T-72 is a product of traditional Soviet design philosophy. Its designers used proven components whenever possible, improved existing components where required, and, only when necessary, designed new components. The major new components in the T-72 are the 125-mm cannon, the track, and the suspension.

By US standards the poor night vision capability of the T-72 is a major deficiency.

Serial production of the T-72 began in 1974 and reached a high of about 2,000 in 1979.

Contents

Figures

The Soviet T-72 Tank Performance (U)

Predictions by skeptics that the appearance on the battlefield of antitank guided missiles (ATGMs) would bring to an end the tank's domination of the field of battle have not come true. Conclusions on the role and place of tanks in future wars, made by Soviet military science even before World War II, would remain valid after that war as well. The laws and patterns of employment of tank troops, discovered by our science, have not lost their practical significance. The development of powerful antitank weapons, including ATGMs, has not diminished the significance of tanks.

—A. Babadzhanyan, Chief Marshal of Armored Troops

14 March 1980
Moscow, USSR

Introduction
This assessment evaluates the combat capability of the latest known deployed Soviet tank, the T-72. The important traits assessed are:

- Firepower—the ability of the T-72's gun and kinetic-energy (KE) ammunition to penetrate the frontal armor of US tanks.
- Armor protection—the ability of the T-72 frontal armor to stop penetration by US tank munitions, antitank guided missiles (ATGM), and antitank rockets.
- Technology integration—the important subsystem technology levels and how they are integrated in the T-72 design to form an effective weapon system.

This assessment will compare the T-72 against US tank and antitank weapons, for in no other way can its firepower and armor protection be realistically evaluated. However, this technical performance assessment is not a war game nor does it consider battlefield scenarios. In combat, both US and Soviet tanks are employed as part of a combined arms team composed of tanks, armored infantry, and artillery. The full capabilities of the tank are only realized when the tank serves as part of the combined arms team. The outcome of a battle will depend on the factors of command and control, tactics, training, logistics, and terrain as well as the characteristics of individual weapons systems. For example, an assessment of the Sioux horses versus those of the Seventh Cavalry would not have provided a reliable prediction of the outcome of the Battle of the Little Big Horn. And the Israeli defeat of Syrian T-72s in Lebanon may be a modern example of good tactics overcoming enemy weaponry that is superior in some technical aspects.

The most important issue at this time is armor penetration. Tanks are normally compared using the assumption of "engagement over a frontal arc" of protection. Other conditions that influence penetration discussions include the relative aspect angles between opposing tanks due to sloping terrain, and of course, rear or side attacks. In this paper we examine this tank's performance in head-on engagements only and on level terrain. [

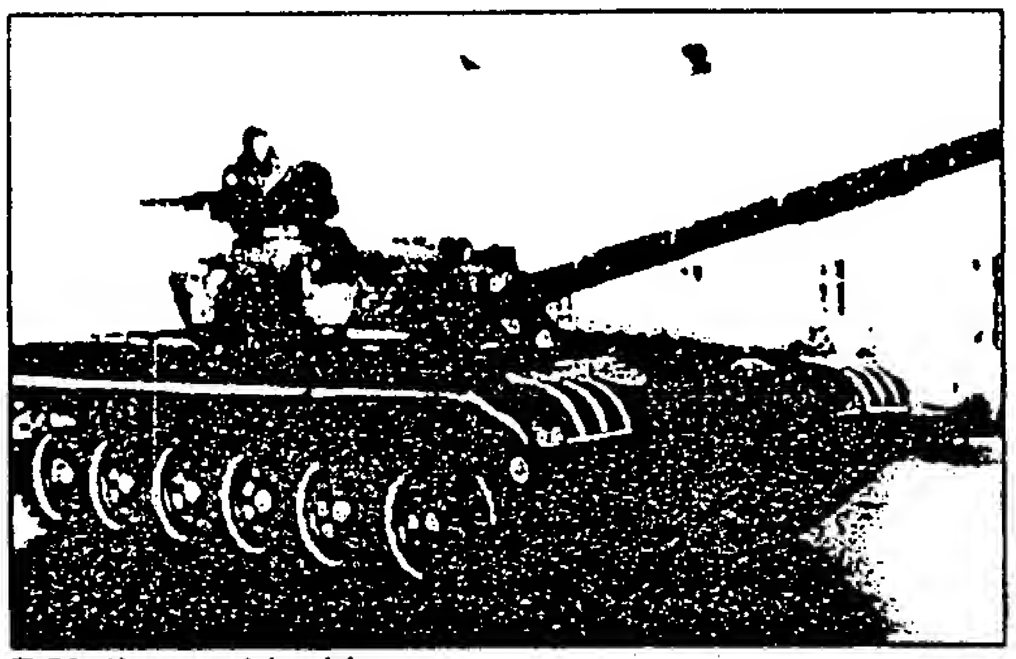
]

Until the development of modern armors like the UK's Chobham and the US's "special," laminate, and ceramic armors, the assessment of armor characteristics was both straightforward and noncritical. Tanks could not carry a sufficient weight of conventional solid-steel armor to protect themselves from penetration by most modern antiarmor weapons. Almost all main battle tank munitions and ATGMs could penetrate conventional armor and defeat enemy main battle tanks at useful combat ranges. There were only minor differences in performance assessments between, for example, the US M-60 and USSR T-62 tanks. The advent of modern armors changed this.

Figure 2

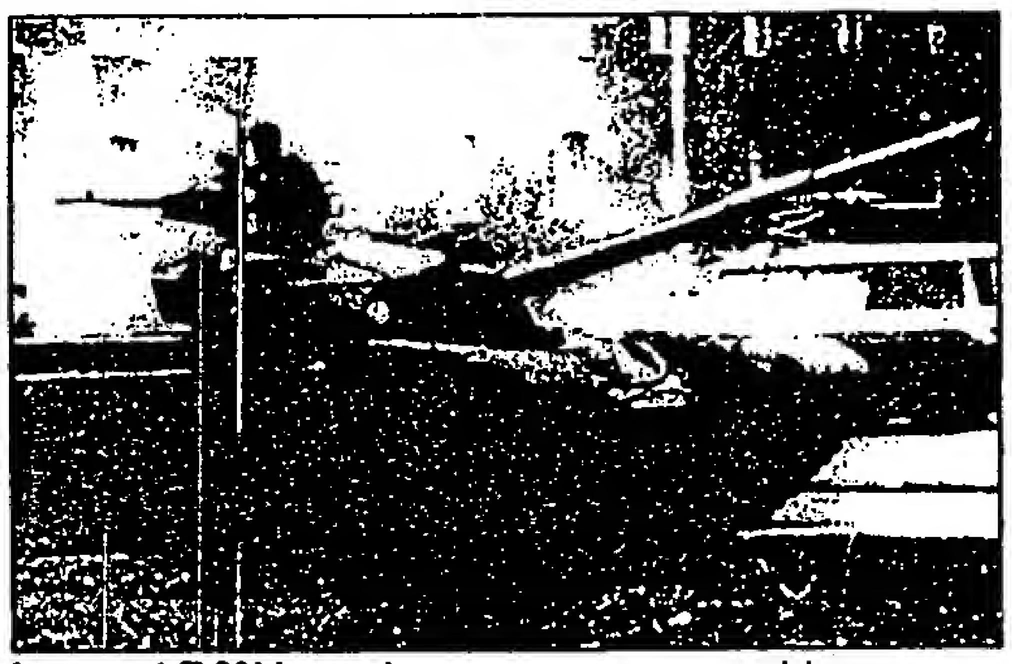
Variants of the T-72 Tank

T-72M[a]



T-72 discussed in this report.

M-1980/1[a]

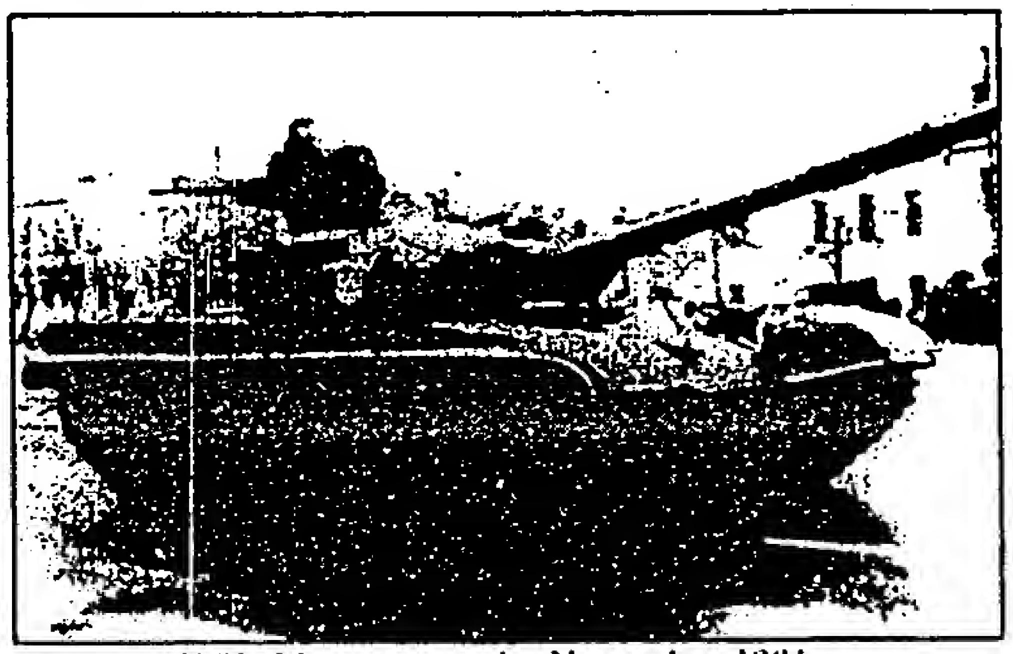


Improved T-72M seen in open-source press and in October 1981 Berlin parade.

M-1981/2[a]

Possible improved T-72 seen in Red Star Newspaper, 10 September 1981.

M-1981/3[a]



Improved T-72. Moscow parade, November 1981.

[a] NATO designation

Now it is possible to field a tank that can be protected against most, if not all, opposing tanks and ATGMs if attacked frontally. The Soviet T-64, in production since 1970, and the T-72, in production since 1974, belong to this new generation of tanks. On the Free World side, the US M-1 tank, the German (FRG) Leopard II, and the British Challenger also have modern, nonhomogeneous armors

Photographs of T-72 variants are presented in figure 2.

Computer drawings of the T-72M tank are shown in figure 3.

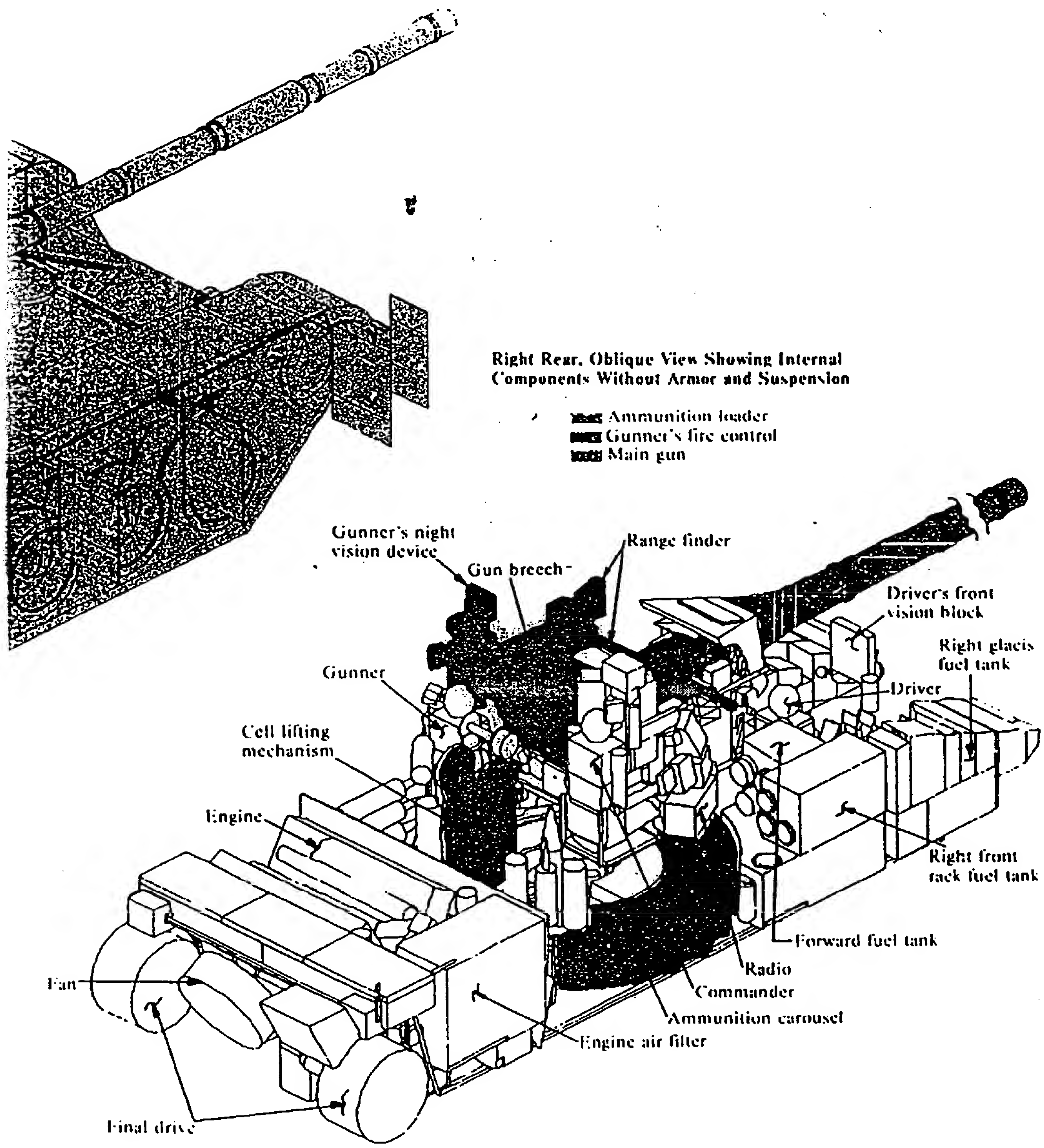
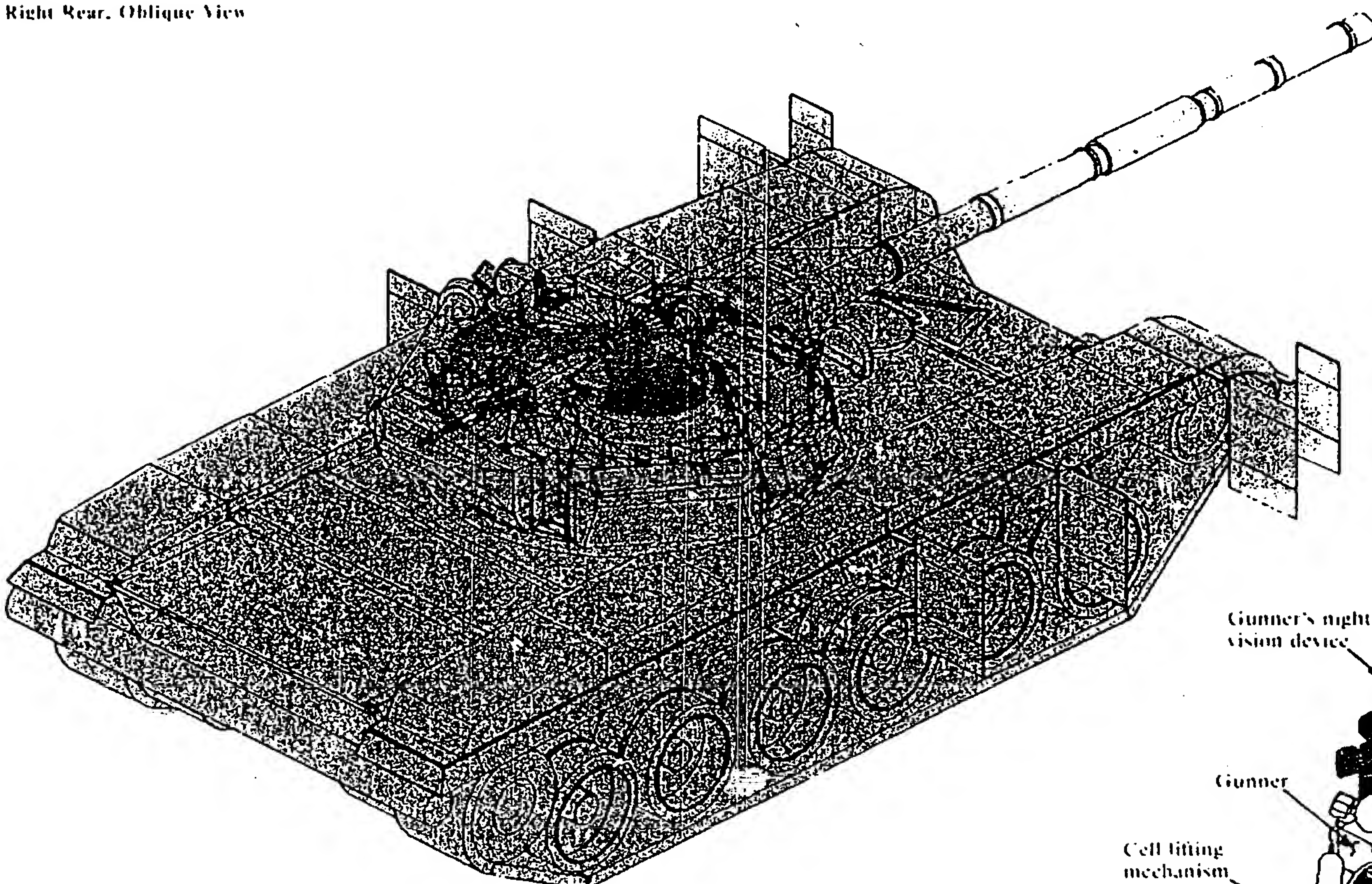

Right Rear, Oblique View Showing Internal Components Without Armor and Suspension
Ammunition loader
Gunner's fire control
Main gun
Gunner's night vision device
Gun breech
Range finder
Driver's front vision block
Right glacis fuel tank
Gunner
Driver
Cell lifting mechanism
Engine
Right front rack fuel tank
Forward fuel tank
Radio
Commander
Ammunition carousel
Engine air filter
Fan
Final drive

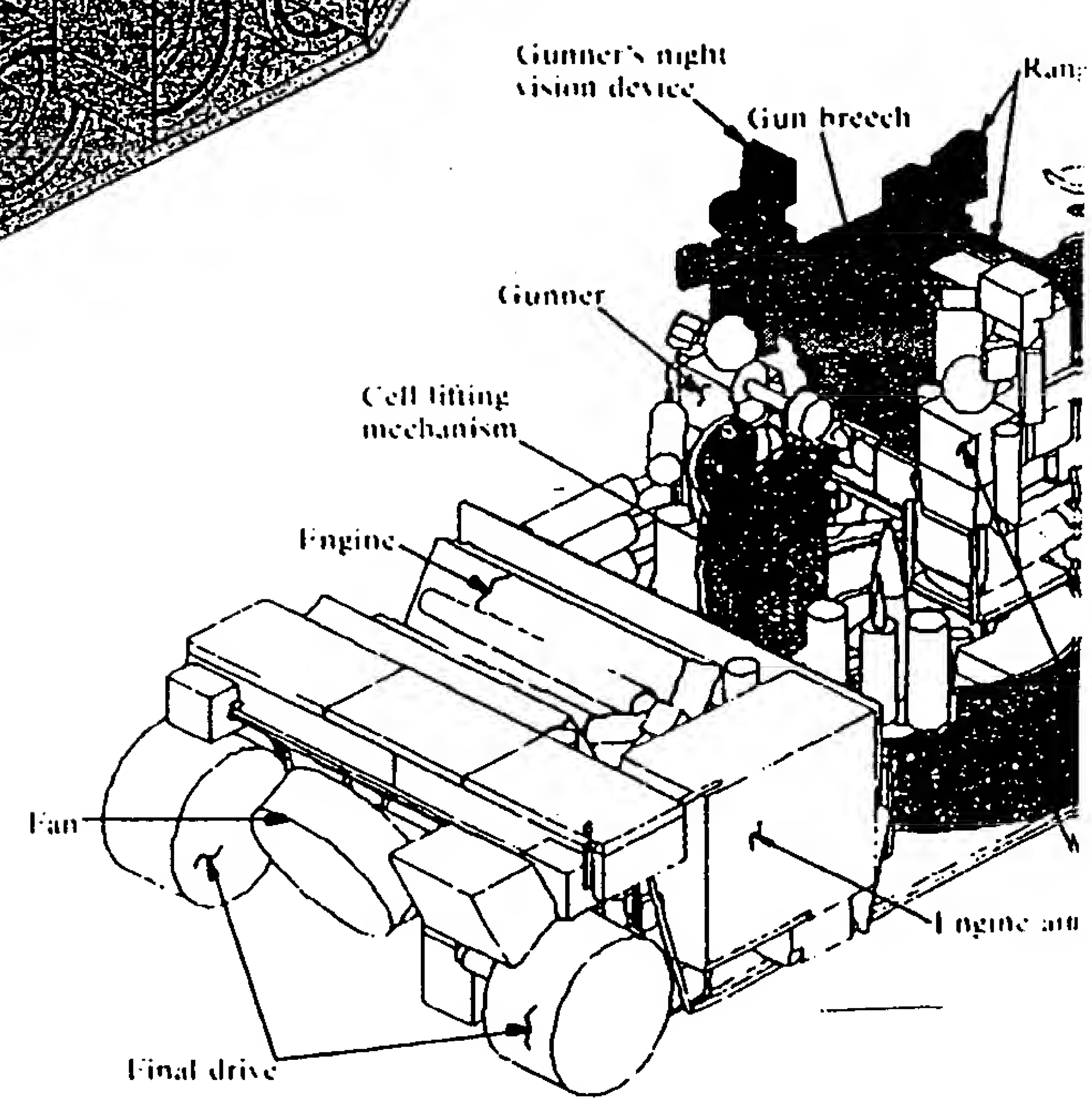
Figure 3

US Computer Drawings of T-72 M Tank

Right Rear, Oblique View



Right Rear, Oblique
Components Without



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Most of the data in this report are on the export tank, the T-72M. Soviet specifications for the T-72M are provided in appendix A. We assume that the T-72 deployed with Soviet troops is at least as good as the export model. The equal reported weights, indicating identical armor protection, and the same model gun and fire-control equipment suggest the export and domestic models are identical.

T-72 Combat Experience

T-72 tanks have seen combat in the recent Iraq-Iran war and the 1982 Israeli incursion into Lebanon. T-72s are not being used by the Soviets in Afghanistan. [ ] reporting from the Iraq-Iran war indicated Iraqi T-72s were destroyed, but engagement details are inconclusive. We are not sure of what weapons were used by the Iranians to destroy Iraqi T-72s, nor have we been able to discover damaged T-72s on the battlefield.

[ ]

Important Factors in Assessing Modern Tanks

Firepower. A tank's capability to kill enemy tanks is of paramount importance. A commander faces an almost insurmountable tactical handicap when his tank cannot kill enemy tanks in a frontal confrontation, or when his tanks can be defeated at 2,000 meters' range, but he can only defeat the enemy's tanks at 1,000 meters' range.

In this assessment firepower will address the performance of the gun and ammunition. Fire control will be discussed separately in the Integration of Technology section. The assessment of firepower will assume adequate fire-control equipment to fully exploit the capabilities of the gun-ammunition system.

Armor Protection. Of almost equal importance is a tank's capability to prevent penetration by enemy antitank weapons. However, armor protection plays a significant role in more than just a tank-on-tank duel. It determines what other enemy weapons besides tanks and ATGMs are effective or ineffective in the antitank role. [ ]

Design and Technology Integration. The integrated design that makes a tank an effective weapon system is the third important factor in assessing a tank. The design of a modern tank weapon system must consider a combination of factors such as user specifications, technology available, producibility, cost, reliability, and maintainability. Analysis of individual subsystem components of the tank provides insights into the T-72's performance, intended role, and resources the Soviet Union has committed to produce this weapon system

Mobility. We did not attempt an assessment of the T-72's mobility for several reasons (basic major characteristics are noted in table 1). First, as part of the combined arms team, the tank cannot effectively move faster than the slowest part of the team—in combat the tank cannot run away from the accompanying infantry. Second, recent studies have been unable to quantify the advantages obtained from increased mobility/agility. And third, modern tanks have such similar mobility characteristics that even if mobility could be quantified, there would be little differences.

Table 1

Basic Mobility Characteristics of Soviet T-72 and US M-1 and M-60A3 Tanks

	Soviet T-72	US M-1	US M-60A3
HP/tonne	19.02		
Fuel consumption *(liters/kilometer)*	2.40		
Ground pressure *(kilograms/square centimeter)*	0.83		
Maximum speed *(kilometers/hour)*	60		
Cruising range *(kilometers)*	500 650 [a]		

[a] With external fuel barrels.

The Soviets also state that their BM-9 or BM-12 KE rounds fired by this gun will penetrate 350 mm of rolled homogeneous armor (RHA) at vertical impact, or 200 mm of RHA at 60 degrees' obliquity at 2,100 meters' range. (The BM-9 rounds exported with the T-72 were manufactured in 1970 and represent technology circa 1965.) Also, we now know that the Soviets have at least one newer KE round. US engineering analysis, using the launch parameters of the 2A46 cannon, projects the penetration performance of the new round to be 410 to 440 mm of RHA at 2,000 meters' range.

According to US, FRG, and other studies, most tank engagements in Europe are expected to occur at ranges closer than 2,000 meters; at these ranges, KE rounds have more penetrating power (proportional to the velocity squared).

. The technical standard used worldwide to compare the performance of rounds, either KE or high-explosive antitank (HEAT), is "penetration in millimeters of RHA." (Available Soviet data has been expressed in these units.) Optimizing a KE penetrator's geometric and material properties to penetrate one type of armor might degrade its performance against others.

Thus, although the available information bounds the penetration, test firings must be conducted to obtain exact data on the round's performance against a specific armor

The T-72 also fires a high-explosive antitank (HEAT)[1] round designated BK-14M. The Soviets have stated the round will penetrate 500 mm of RHA at impact normal to the surface

US engineering analysis based on the performance of other known Soviet HEAT ammunition and known Soviet technology in shaped-charge warheads confirms the Soviet claim.

[1] The penetration capability of HEAT rounds is range independent because the energy driving the penetration is carried in the warhead. (It is not the result of warhead velocity as is the case of KE munitions.) The HEAT munition is less accurate than the KE projectile because it has a lower velocity and is more dependent on the fire-control system. (U)

Figure 4

The Soviets have another high-explosive (HE) round, the OF-19, for use against soft targets such as personnel and unarmored vehicles. It has a maximum range of 5,000 meters in direct fire or 10,000 meters if indirect fire techniques are used.

The T-72 carries a basic ammunition load of 39 rounds. The basic load will be a mix of KE, HEAT, and HE rounds. Twenty-two rounds are carried in the automatic loader and the remaining 17 are stowed below the turret ring. These 17 rounds must be loaded manually either into the automatic loader or directly into the gun.

T-72 Armor Protection

In tanks with conventional solid-steel armor (RHA) there is a direct relationship between the protection provided against HEAT and KE munitions. With modern armors, however, protection can be enhanced against either KE or HEAT munitions, with the armor usually finally being designed to defeat specific threats. The export T-72, with its solid-steel turret and a laminate glacis, has both armor designs. It is therefore necessary to assess the armor protection of the turret and glacis individually and against both KE and HEAT threats.

Turret. We assess the T-72's turret has sufficient armor to:

Figure 5

Our assessment of the protection provided by the T-72 turret armor was based on the following:

- A Soviet T-72 drawing indicates the turret thickness is about 475 mm at one point (see figure 6).

Figure 6

Cutaway View of T-72 Turret

Top View

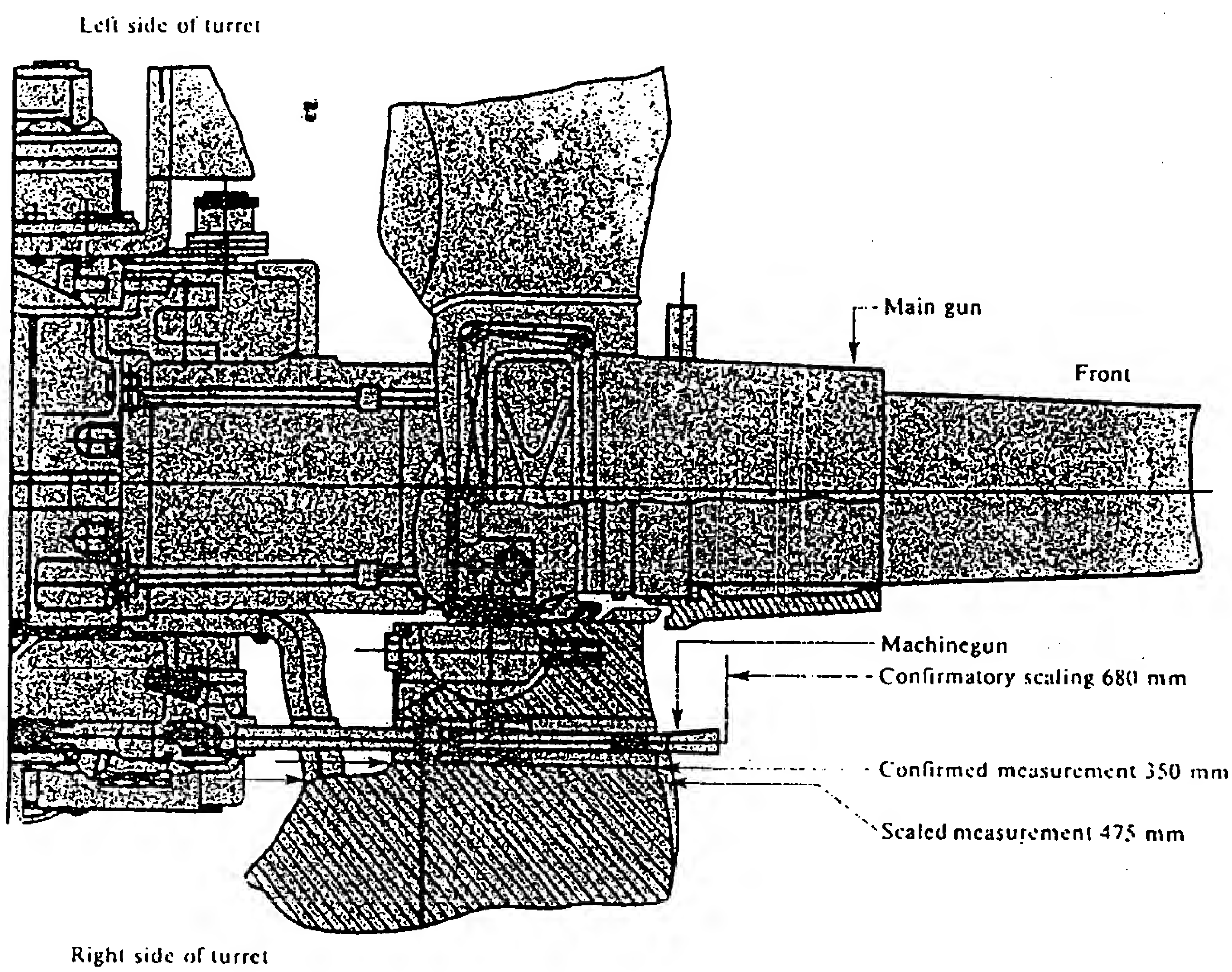


Figure 7

[redacted]

[redacted]

- [redacted]

- [redacted]

[redacted] information on the front glacis armor protection is as follows:

- The Soviet guarantee (to recipient countries), as stated above. Note that the guarantee does not state specifically whether it applies to the turret or the glacis. We assume, however, that the Soviets followed normal design practice, and therefore the guarantee applies to both.

- [redacted] confirm that the front glacis is a three-layer laminate. The first (outside) layer is 80-mm-thick, high-carbon steel and the third layer is 20-mm-thick, high-carbon steel. The inner layer is described to be 100-mm-thick, compressed polyurethane (CP) with a density one-fourth that of the steel layers

Figure 8

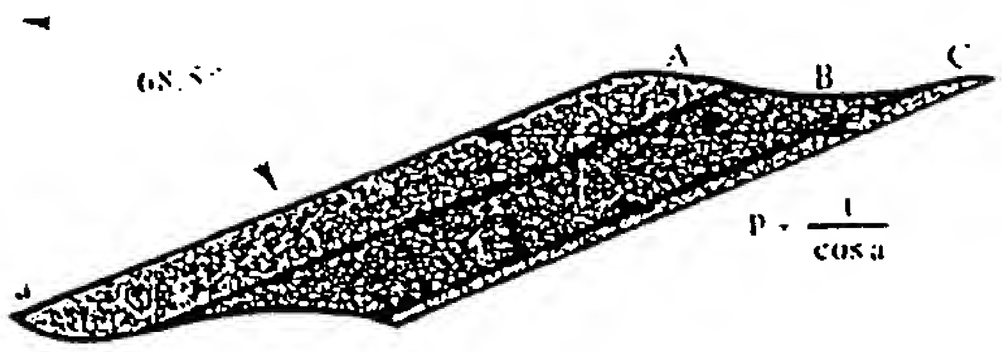
Direct confirmation of the protection provided by the T-72's laminate front glacis was not possible because we did not have a CP material with the density stated above. However, we were able to assess the technological risk [2] associated with the development of the CP layer of the glacis to provide the required HEAT and KE protection as follows:

[2] Technological risk is a qualitative term that considers the level of effort, money, resources and time, and the probability of technical failure. Low risk means low effort and low probability of failing, high risk means high level of effort and high probability of failure.

- Using information from the Soviet guarantee and penetration data on US HEAT and KE munitions, we determined the amount of protection the laminate glacis must provide against these munitions to match the protection provided by the turret.

Figure 9

Characteristics of T-72 Front Glacis Armor



a Angle of glacis
p Line-of-sight (LOS) or munitions path-length
t Thickness

Layer	Material	t (mm)	p (mm)	LOS Areal Density (kg/m²)
A	High carbon steel	80	216	1,672.6
B	Compressed polyurethane	100	270	520.3
C	High carbon steel	20	54	416.2
Total		200	540	2,609.1

- We determined the equivalent protection, in mm of RHA, that the CP layer must provide in addition to the actual 270 mm (projectile path length) of RHA protection provided by the other two layers. (Characteristics of the T-72 front glacis armor are presented in figure 9.)

- For HEAT protection provided by the CP layer, we compared the performance required by the CP layer with the performance of materials tested [ ]

- For KE protection provided by the CP layer, we compared the performance required by the CP layer with the performance provided by an equal-weight layer of RHA. US R&D work has shown that materials do exist that provide this weight-equivalent protection against KE munitions.

The Soviets had one additional technological risk in developing a successful CP layer. This involved the tendency of CP-like materials to defeat but shatter upon impact of the first round, whether a HEAT or a KE round. [ ]

[ ]

[ ]

Data on Soviet munitions are also presented in figure 10. We assume that if the Soviets did not have data on US munitions during the development time frame of the T-72 they probably tested their own munitions against their armor. (This is standard procedure in most countries because it allows repeatable and more extensive testing than would be possible with the usually hard-to-obtain enemy rounds.) Also, we assume that in developing a new tank's armor the Soviets attempted to design it to defeat their own best munitions. However, our assessment of Soviet munitions leads us to the conclusion that the T-72 would have protection against the Soviet HEAT round, but not the KE round.

Figure 10

Figure 11

[redacted]

Our analysis of the protection provided by the T-72 armor was restricted by another uncertainty, although it was not as critical as the front glacis material parameters. We do not know how the Soviets define the 60-degree frontal protection arc. Figure 11 illustrates possible differences in armor protection with different locations of the apex of the protection arc. The farther back the apex, the more armor that must be added to the sides. This can cause a severe weight penalty, but results in increased vehicle protection.

As is evident in figure 10, when the T-72 was being developed the dominant threat of both the United States and the USSR was the HEAT munition. The apparent Soviet design decisions to use a thick cast-steel turret and a laminate glacis provided sufficient matched protection against known 1965-74 munitions, with low technological advances seemingly required on the Soviets' part. [redacted]

Integration of Design and Technology

The Soviets seem to have carefully integrated a variety of armored vehicle technologies into the T-72. Their design philosophy seems to have been to use proven components whenever possible, modify proven components as necessary, and, when this was not possible, design new components. As is evident in figure 12, systems for underwater fording; radiation protection; nuclear; biological, and chemical warning/protection; night vision; and gun stabilization probably originated from designs dating back to the T-55, which was fielded around 1958. All other requirements were filled using T-64 or newly designed components.

[redacted] have not permitted a clear delineation between the differences in the roles of the T-64 and the T-72. [redacted] t at least in initial production numerous problems existed with the T-64's automatic loader, engine, track, and suspension systems. The T-72's laminated front glacis, transmission, and rangefinder seem to have been derived from the T-64. Also, the automatic loader, track, and suspension in the T-72 were newly designed components apparently designed to correct problems in these areas in the T-64. The T-72 has a cast, solid-steel turret rather than the cored turret reported to be on the T-64. We do know that the same model 125-mm smooth-bore cannon is used on the T-72 and T-64A. The engine of the T-72 is a direct, although modified and improved descendant of the T-55's V-12 diesel engine.

Figure 12

Comparison of USSR and US Tank Technology Development

■ First deployment of technology by USSR
□ Reuse of first deployed technology by USSR
○ Technology developed specifically for T-72

▣ First deployment of technology by US
□ Reuse of first deployed technology by US

	T-55 1955	T-62 1961	T-64 1970	T-72 1974	M-60A1 1962	M-60A3 1978	M-1 1979
Underwater fording	■	□	□	□			
Radiation protection liner	■	N/A	□	□			
Nuclear, biological, and chemical warning and protection	■	□	□	□			
Night vision							
Active infrared	■	□	□	□	▣		
Passive, driver				○		▣	□
Passive, commander and gunner						▣	b
Thermal sight						▣	▣ b
Firepower							
Stabilization	■	□	□	□		▣	▣ b
Improved main gun			a	a	▣ 105mm	□	□
Automatic loader			■	○			
Improved fire control			■	□		▣	▣ b
Advanced armor							
Turret			■	○			▣
Glacis			■	■			▣
Mobility							
Engine	■		■	□ c			▣
Transmission			■	■			▣
Track and suspension			■	○			▣

a 125-mm gun. Uncertain whether first used on T-72 or T-64.
b Although same technology, M-1 does not use M-60A3 components.
c Improved T-55 engine.

To illustrate the difference between Soviet and US design philosophy figure 12 also shows M-1 tank development. In the US M-1 tank all components except for the 105-mm main gun are new. (The M-1's main gun will presumably be replaced by a new 120-mm gun in 1984.)

US evaluation of Soviet tanks up to the T-62 indicated the tanks had poor fire control, and excessive maintenance and driver training problems because of the steel-plate clutches and manual transmissions used. These deficiencies were overcome in the T-72. The improved fire control and power train components are on the T-64 also.

Fire Control.[3] The T-72's fire control system represents a significant technological advance over previous Soviet systems. It combines an optical gyrostabilized sight, whose field of view is stabilized in elevation, and a monocular split-image rangefinder. The fire control system accomplishes the following:

- Automatic generation and setting of gun elevation angles in the sight reticle for the measured range for all types of ammunition.
- Automatic change of the ballistic cam (the heart of the gun elevation computer) when the ammunition type is selected. Each type of round because of its unique characteristics has a distinct trajectory and requires individual prediction of the elevation to ensure a target hit.
- Power elevation and traverse of the stabilized gun and coaxial machine gun in the automatic or semi-automatic mode.
- Automatic change of the elevation angle (after initial target range measurement) with change in range due to tank movement.
- Fire control of both the main gun and coaxial machine gun.

The known accuracy of the rangefinder is:

Range (meters)	Error (percent)
1,000 to 2,000	2.5
2,000 to 3,000	3.5
3,000 to 4,000	4.5

Transmission. The T-72's (and T-64's) transmission design is an interesting engineering solution to clutch maintenance and driver-training problems. The design avoids the complexities and the efficiency losses associated with fully automatic transmissions, and is space efficient. It includes:

- Use of only planetary gear sets (which are always in constant mesh) activated by hydraulic pressure.
- Use of a driver-applied clutch pedal for stopping and starting the tank. This clutch pedal only controls the hydraulic pressure to the planetary gear sets, thus eliminating all clutch-wear problems.
- Driver selection of the gear the transmission will be in using a selector lever. (Seven forward and one reverse speeds are available.) Because the transmission has constant-mesh planetary gear sets, the clutch is not used when shifting.
- An interlock that prevents the driver from selecting the wrong speed. The interlock will allow the driver to move the gear selector lever only when the engine and transmission speeds are synchronized.
- Identical left and right gear boxes that incorporate the shifting, steering, and braking functions, and left and right final drives that provide the final gear reduction. This arrangement makes efficient use of the space on each side of the engine. Although no new transmission theory was used, this engineering solution optimizes the best features of a planetary gear transmission and eliminates the less desirable characteristics of an automatic transmission.

Automatic Ammunition Loader. The T-72's automatic loader, although a new design compared to the T-64's, provides the same advantages:

- It eliminated the fourth crewmember, the loader. This conserves interior volume and leads to a smaller, lighter tank.
- It permits rapid loading of the main gun.[4] The maximum rate of fire is six to eight rounds per minute. Although it is doubtful that fire control procedures will allow use of this maximum rate of fire, the automatic loader ensures that a round is always loaded in the gun and ready for firing when the commander is ready.
- It provides for stowage of ammunition well below the turret, thereby increasing survivability

In user tests the T-72's automatic loader has reportedly loaded 3,000 rounds without a malfunction. Considering the complexity of this system, such performance reflects excellent design and testing.

[4] The ammunition is caseless with a stub metal base obturator (for sealing the base of the projectile when fired). The obturator is ejected after firing, leaving the turret clear of any spent round remains

Night Vision Deficiency. The T-72's night vision capability is a major deficiency by US standards. The Soviets continue to use an active infrared (IR) system that is virtually unchanged from the one on the T-55 tank (1958 vintage). This IR system provides an effective night-firing capability up to a range of only 800 meters. Further, the tank commander can see up to only 400 meters with his active IR night sight. As for the driver, he has an image intensifier device that permits him to see up to only 60 meters in not less than one-quarter moonlight or equivalent natural illumination. For darker nights, however, an active IR system, also provided, must be used.

The T-72's deficiency in night vision is an anomaly. We do not know if active IR is the only user requirement or if there is a Soviet technology or production problem. The Soviets fielded a passive IR image intensifier sight for the gunner on the BMP vehicle in 1976. This system provides an effective firing capability to 800 meters.

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Appendix A

Specifications of the T-72M Tank

2.1. Vehicle Data	
2.1.1. General	
Tank type	Medium
Weight (combat loaded)	41 t
Crew	3
Specific horsepower	19 hp/t
Ground pressure	0.83 kg/cm²
2.1.2. Dimensions	
Length:	
With gun pointed forward	9,530 mm
With gun pointed rearward	9,670 mm
Hull length (over mudguards)	6,910 mm
Hull width:	
Over removable flaps	3,460 mm
Over tracks	3,370 mm
Height (over turret roof)	2,190 mm
Track length on the ground	4,270 mm
Ground clearance:	
To hull bottom	470 mm
To hull protrusions	428 mm
2.2. Performance	
2.2.1. Speeds of Movement	
Average speed:	
On dirt road	35 to 45 km/h
On trail	25 to 30 km/h
On highway	Up to 50 km/h
Maximum speed on highway	60 km/h
Cruising speed (at 2,000 rpm):	
1st range	7.32 km/h
2nd range	13.59 km/h
3rd range	17.16 km/h
4th range	21.47 km/h
5th range	29.51 km/h
6th range	40.81 km/h
7th range	60.00 km/h
Reverse	4.18 km/h
2.2.2. Consumption of Fuel and Lubricant and Cruising Range	
Fuel consumption (per 100 km):	
On dirt road	260 to 450 l
On highway	240 l

2.2. Performance (continued)	
Oil consumption (per 100 km) on dirt road	3 to 10 l
Cruising range:	
On dirt road:	
On fuel in main fuel tanks	320 to 480 km
With barrels	420 to 600 km
On highway:	
On fuel in main fuel tanks	500 km
With barrels	650 km
2.2.3. Cross-Country Performance	
Maximum grade ascending ability	30°
Maximum heeling angle	25°
Maximum trench crossing width	2.6 to 2.8 m
Vehicle obstacle ability	0.85 m
Fording depth:	
Without preliminary preparation	1.2 m
After 5-min preparation	1.8 m
Underwater stream crossing ability (current velocity of up to 1.5 m/s):	
Width of water barrier	Up to 1,000 m
Depth of water barrier	5.0 m
2.3. Weapons System	
2.3.1. Gun	
Type	Smooth bore
Bore size	125 mm
Model	2A46
Effective rate of fire:	
With automatic loading	Up to 8 r/min
With manual loading	1 to 2 r/min
Ammunition	Armor-piercing discarding sabot (APDS), high-explosive fragmentation (HEF), and high-explosive antitank (HEAT) shells
Loading	Separate
Maximum range of aimed fire using rangefinding sight TPD 2-49:	
APDS	4,000 m
HEAT	4,000 m
HEF	5,000 m

2.3. Weapons System (continued)

Maximum range of aimed fire using night sight TPN 1-49-23	600 to 800 m
Maximum HEF range using elevation level	9,400 m
Point-blank range (with 2-m high target):	
APDS	2,100 m
HEAT	960 m
Height to bore of gun	1,651 mm
Normal length of recoil	270 to 320 mm
Maximum length of recoil	340 mm
Recuperator capacity	4.7 l
Recoil brake capacity	7.3 l
Pressure in recuperator	63 to 67 kg/cm²
Mass of tipping parts of gun without armor shield and stabilizer	2,400 kg
Firing method	Using volatile igniter, electric trigger, or mechanical trigger
2.3.2. Coaxial Machinegun	
Model	PKT
Bore size	7.62 mm
Maximum range of aimed fire using sight	1,800 m
Effective rate of fire	Up to 250 r/min
Feeding	Belts
Number of cartridges in belt	250
Method of firing	Using remote electric trigger and mechanical trigger
Mass of machinegun	10.5 kg
2.3.3. Effective Field of Fire for Gun and Coaxial Machinegun	
Traverse of turret	360°
Angle of elevation (with stabilizer switched off)	13°47'
Angle of depression (with stabilizer switched off):	
On bow	6°13'
On stern	3°47'
2.3.4. Antiaircraft Machinegun Mount ZU-72	
Type	Independent, open
Control	Manual
Time to prepare for action	60 s
2.3.4.1. Antiaircraft Machinegun	
Model	NSV-12.7
Bore size	12.7 mm
Maximum range of aimed fire:	
At aerial targets	1,500 m
At ground targets	2,000 m
Feeding	Belts
Number of cartridges in belt	60
Rate of fire	680 to 800 r/min
Method of fire	Hand actuation
Mass	25 kg
2.3.4.2. Effective Field of Fire for Antiaircraft Machinegun	
Angle of traverse	360° (with setout of antenna)
Angle of elevation	+75°
Angle of depression	−5°
2.3.4.3. Sight of Antiaircraft Machinegun Mount	
Model	K10-T
Magnification	1X
Mass	0.4 kg
2.3.5. Submachinegun	
Number per vehicle	1
Model	AK-47
Bore size	7.62 mm
Mass with loaded magazine	4.8 kg
2.3.6. Flare Pistol	
Number per vehicle	1
Bore size	26 mm
2.3.7. Unit of Ammunition	
Gun rounds	39
Cartridges for machinegun PKT	2,000
Cartridges for machinegun NSV-12.7	300
Cartridges for submachinegun AK-47	300
Hand grenades	10
Flares for flare pistol	12
Mass of main gun rounds:	
With APDS shell	19.7 kg
With HEAT shell	29.0 kg
With HEF shell	33.0 kg
2.3.8. Automatic Loading Gear	
Type	Electromechanical, with preset loading angle
Capacity of rotary conveyor	22 rounds
Rate of conveyor rotation	Up to 70°/s
Loading interval	8 s

2.3. Weapons System (continued)

Standby drives for automatic loading gear	Hand drive for rotary conveyor and shell lifting mechanism
Ramming	Separate
Rotary conveyer loading times	4 to 5 min
2.3.9. Stabilizer	
Type	Double plane (stabilizing in elevation and azimuth), electrohydraulic
Model	2e28M
Rate of gun laying in elevation in automatic mode:	
Minimum	Not in excess of 0.05°/s
Maximum	Not less than 3.5°/s
Rate of turret traverse in automatic mode:	
Minimum	Not in excess of 0.0[illegible]°/s
Maximum	Not less than 6°/s
Rapid transfer (throw over)	Not less than 18°/s
Rate of turret traverse controlled by commander	Not less than 18°/s
Emergency traverse controlled by driver	Not less than 18°/s
Rate of turret traverse in semiautomatic mode:	
Minimum	Not more than 0.3°/s
Maximum	Not less than 6°/s
Rapid transfer	Not less than 20°/s
Time to prepare stabilizer for operation	2 min
Time of continuous operation under various climatic conditions in temperature range from −40 to +50°C	Not more than 4 h (not in combat conditions)
Fluid used in stabilizer hydraulic system	MGYe-10A
Power consumed by stabilizer (mean)	3.5 kW
Mass of stabilizer equipment with working fluid	Not more than 319 kg

2.4. Sighting and Fire Control Instruments and Navigation Equipment

2.4.1. Rangefinding Sight	
Type	Monocular, stereoscopic, with independent stabilization of field of view in vertical plane
Model	TPD 2-49
Magnification	8X

2.4. Sighting and Fire Control Instruments and Navigation Equipment (continued)

Field of view:	
Sight branch	9°
Rangefinding branch	1°40'
Periscopic distance	155 mm
Rangefinding limits	1,000 to 4,000 m
Accuracy of rangefinding	3 to 5 percent
Mass	80.6 kg
Time to prepare sight for operation	2 min
Time of continuous operation under various climatic conditions in temperature range from −40 to +50°C	Not more than 4 h (not limited in combat conditions)
2.4.2. Night Vision Sight	
Type	Electronoptical monocular, periscopic
Model	TPN-1-49-23
Magnification	5.5X
Field of view	6°
Operating range	600 to 800 m
Periscopic distance	260 mm
Infrared source	One spotlight L-2AG (L-2AGM) with infrared filter
Power pack	BT6-26M
Mass of sight	16.6 kg
2.4.3. Optical Vision Devices	
Tank commander's periscope:	
Type	Prismatic
Model	TNP-160
Number per vehicle	2
Mass	3.6 kg
Driver's periscope:	
Type	1-power, heated, prismatic, with temperature regulator
Model	TNPO-168V
Gunner's periscope:	
Type	Prismatic
Model	TNP-165A
Mass	2.85 kg
Auxiliary prismatic devices:	
Number	5 (2 for driver, 2 for tank commander, and 1 for gunner)

2.4. Sighting and Fire Control Instruments and Navigation Equipment (continued)

Model	TPN-65
Mass	0.7 kg
2.4.4. Infrared Vision Devices	
Tank commander's periscope:	
Type	Combination (night and daytime vision), electron-optical, binocular
Model	TKN-3
Magnification:	
Daytime vision system	5X
Night vision system	4.2X
Field of view:	
Daytime vision system	10°
Night vision system	8°
Periscopic distance	200 mm
Operating range at night	300 to 400 m
Infrared source	Spotlight OU-3GK (OU-3GKM) with infrared filter
Mass	12.5 kg
Driver's periscope:	
Type	Electronoptical, binocular
Model	TVNYe-4 PA
Magnification	1X
Field of view	35°
Operating range	60 m with headlight used for illumination and 100 m at ambient skylight intensity of 0.005 lumens
Infrared source	Headlight FG-125 with infrared filter
Power pack	BT-6-26 Ye (output voltage, 17 to 20 kV)
2.4.5. Navigation Equipment	
Course indicator	Gyro direction indicator GPK-59
Azimuth indicator of turret traversing mechanism	
Elevation level	

2.5. Power Unit

2.5.1. Engine	
Type	Four-stroke, multifuel, liquid-cooled diesel with engine-driven centrifugal supercharger

2.5. Power Unit (continued)

Model	V-46-6
Number of cylinders	12
Cylinder arrangement	In a 60-deg V
Gross horsepower at n = 2,000 rpm on diesel fuel	780 hp
Gross torque at n = 1,300 to 1,400 rpm on diesel fuel	315 plus or minus 10 kg/m
Maximum idling speed	Not over 2,300 rpm
Minimum stable speed	Not over 800 rpm
Gross horsepower-specific diesel fuel consumption	180 kg/hp-h
Specific oil consumption at n = 1,800 rpm	Not over 8 kg/hp-h
Overall dimensions:	
Length	1,480 mm
Width	896 mm
Height	902 mm
Dry mass with exhaust manifolds and centrifugal oil cleaner MH-1 installed	980 kg
Firing order	1L - 6R - 5L - 2R - 3L - 4R - 6L - 1R - 2L - 5R - 4L - 3R
Supercharger:	
Type	Centrifugal, mechanically driven
Model	H-24
2.5.2. Fuel System	
Fuel used:	
In hot season	Diesel fuel, grade DL [a]
In cold season	Diesel fuel, grade DZ or DA
In hot or cold season in absence of diesel fuel	Fuel, grade TS-1, T-1, and T-2, and non-ethylate gasoline A-66 and A-72 [b]
Fuel system capacity:	
With barrels	1,590 l
Without barrels	1,200 l
Capacity of fuel tanks:	
Internally mounted	705 l
Externally mounted	495 l

Footnotes at end of appendix.

2.5. Power Unit (continued)	
Fuel filters:	
Primary	Gauze
Secondary	TFK-3, with filtering elements
2.5.3. Air Supply System	
Type of air cleaner	Double stage, with dust removed from collector by ejection. First stage, cyclone; second stage, filtering elements
Number of cyclones	96
Number of elements	8
2.5.4. Lubricating System	
Oil used in hot and cold seasons	M-16 KHP-3 (principal), MT-16 (substitute)
System capacity	65 l
Capacity of oil tanks:	
Main oil tank	27 l
Replenishing oil tank	38 l
Auxiliary (externally mounted) oil tank	35 l
Minimum permissible amount of oil in tanks	20 l
Oil filtering devices:	
Wire slotted filter	MAF
Centrifugal oil cleaner	MTs-1
Oil priming pump	MZN-2
2.5.5. Cooling System	
Type	Liquid, return, forced with air circulating through radiators and coolers by fan
Capacity	90 l
Coolant used:	
In hot season	Water with three-component additive
In cold season	Antifreeze, grade "40" or "65"
Fan	Centrifugal, with disk friction clutch
2.5.6. Preheating System	
Type of preheater	Injector
Maximum fuel consumption	Not in excess of 9 l/h
Time of continuous operation	Unlimited
2.5.7. Starting System	
Main	Compressed air
Auxiliary	Electric, using starter-generator SG-10-1S

2.5.8. Compressed Air System	
Compressor:	
Type	Piston, three stage, two cylinder, air cooled
Model	AK-150SV
Operating pressure	150 kg/cm²
Capacity	2.4 m³/h
Number of compressed air bottles	2
Capacity of compressed air bottles	5 l
2.5.9. Engine Operating Conditions	
Coolant temperature:	
Recommended:	
With cooling system filled with water	70 to 100°C
With cooling system filled with antifreeze	70 to 90°C
Maximum permissible:	
With cooling system filled with water	115°C
With cooling system filled with antifreeze	95°C (105°C for short period)
Minimum permissible	65°C
Oil temperature:	
Recommended	70 to 100°C
Maximum permissible	115°C (120°C at ambient air temperature of +35°C or higher)
Minimum permissible	65°C
Oil pressure in engine at cruising speed	5 to 10 kg/cm²
Recommended engine cruising speed	1,600 to 1,900 rpm
Recommended engine idling speed	Not less than 800 rpm
2.6. Power Transmission	
Type	Mechanical, with step-up gear unit, two final gear boxes, and coaxial final drives
2.6.1. Transmission Gear Unit	
Type	Step-up gear unit that drives compressor, starter-generator, and fan of cooling system
Transmission ratio	0.706
Mass	320 kg

2.6. Power Transmission (continued)

2.6.2. Final Gear Boxes

Type	Planetary, 8-range (7 forward and 1 reverse), friction clutch-engaged and hydraulically controlled	
Number of friction clutches in each final gear box:		
Steering clutches	2	
Brake clutches	4	
Method of steering	By engaging low range in final gear box on the side of lagging track	
Ratios (i) and rated turning radii (R):	i	R
1st range	8.173	2.79 m
2nd range	4.4	6.04 m
3rd range	3.485	13.42 m
4th range	2.787	13.93 m
5th range	2.027	10.23 m
6th range	1.467	10.10 m
7th range	1	8.76 m
Reverse	14.35	2.79 m
Gear box control	Hydraulic with slide valve mechanically controlled	
Brake control linkage	Mechanical	
Final drive	Planetary	
Final drive transmission ratio	5.454	
Mass of final gear box complete with final drive:		
Left-hand gear box	710 kg	
Right-hand gear box	700 kg	

2.6.3. Lubricating and Hydraulic Control System

Oil used	TSZP-8 (principal), MT-8p (substitute)
Total capacity of system	57 l
Oil tank capacity	42 l
Oil pressure in lubricating line	2 to 2.5 kg/cm²
Oil pressure in hydraulic control system:	
In 1st and reverse ranges, and in final gear box on leading-track side in steer	13.5 to 15 kg/cm²
In 2nd through 7th ranges and in final gear box on lagging-track side in steer	8.5 to 10 kg/cm²

2.7. Track-and-Suspension System

2.7.1. Track Drive System

Type	Endless chain, with track drive sprockets at the rear
Track:	
Type	Rubber bushed
Number of track shoes in each track	96
Width	580 mm
Pitch	137 mm
Mass of track	1,698 kg, ea
Mass of track shoe	15.8 kg, ea
Track drive sprockets:	
Type	With two removable wheels
Number of teeth on track drive sprocket wheel	14
Mass	193 kg, ea
Idler wheels:	
Type	All metal, cast
Mass of idler wheel complete with crank arm	197 kg, ea
Road wheels:	
Type	Double disk, externally cushioned
Number	12
Mass	177 kg, ea
Support rollers:	
Type	Single tire, internally cushioned
Number	6
Mass	31 kg, ea

2.7.2. Suspension System

Type	Independent, torsion bar, with shock absorbers
Shock absorbers:	
Type	Hydraulic, vane
Arrangement	On suspension units of 1st, 2nd, and 6th road wheels
Mass of filled hydraulic shock absorber	66 kg

2.8. Electrical Equipment

Type	dc, single wire (emergency lighting system and USCE bilge pump are in two-wire circuit)

2.8. Electrical Equipment (continued)

Main voltage	27 (+2 or −5) V (48 V for starter circuit)
Main protection means	Automatic circuit breakers and fuse links
Collector ring box	VKU-330-4
Noise suppressors	F-10 and F-5
2.8.1. Storage Batteries	
Type	Starter, lead-acid
Model	6STZN-140M
Number per vehicle	4
Total capacity of storage batteries	280 A/h
Mass of one storage battery with electrolyte	62 kg
2.8.2. Starter-Generator	
Starter-generator:	
Type	dc, protected with compound excitation
Model	SG-10-1S
Mass	70 kg
Generator data:	
Capacity	10 kW
Rated volts	26.5 to 28.5 V
Starter data:	
Horsepower	26 hp
Rated volts	48 V
Generator regulator:	
Type	Contactless, with weather-effect control
Model	R-10TMU
Starter-generator changeover unit	VSP-1M
Starter-generator relay	RSG-10M1
Starter actuating device	PUS-15R
Matching device	PAS-15-1S
2.8.3. Lighting and Signaling Devices	
Headlight with blackout door	FG-127
Headlight without blackout door	FG-126
Horn	SC-314G

2.9. Instruments

Voltammeter	VA-540
Tachometer	TZ-4V
Speedometer	SP-110
Pressure gauges:	
Number	3
Model	TZM-15 (2), ZDMU-6H (1)

2.9. Instruments (continued)

Temperature gauges:	
Number	2
Model	TUZ-48-T
Engine hourmeters:	
Number	2
Model	228-ChP-11
Fuel gauge	TM-2-1S
Clock	SCh-117

2.10. Communication Facilities

2.10.1. Radio Set	
Type	Transceiver, voice, simplex
Model	R-123M
Operating range in communications with radio set of the same model on broken terrain, using 4-m whip antenna:	
With squelch off and no jamming	20 km
With squelch on	13 km
Rated volts	26 V
Rated amperes:	
In simplex	5 A, max
In transmission	9.6 A, max
In standby reception	3 A
2.10.2. Tank Interphone	
Model	R-124
Number of users	4

2.11. Special Equipment

2.11.1. CBR Protection System	
Type	Collective, protecting the crew and equipment inside tank from shock wave and radioactive agents
Sensor	Device GD-1M
Means for building overpressure and cleaning air supplied inside of dust and radioactive agents	Blower-separator
System servos	Mechanical
Servos control equipment	EETS 11-3
Method of system actuation	Automatic and manual
2.11.2. Firefighting Equipment	
Type	Automatic, triple use
Number of cylinders	3
Type of fire-extinguishing liquid	Freon 114B2
Number of fire-sensitive units	14

2.11. Special Equipment (continued)	
Control equipment method of actuation	Automatic and manual
Portable fire extinguisher:	
Number	1
Model	OU-2
2.11.3. Screening Facilities	
Type	Thermal, smoke-generating equipment
Time of continuous operation	Not more than 10 min
Fuel consumption	10 l/min
2.11.4. Underwater Stream-Crossing Equipment	
Method of preparing tank for crossing a water barrier	Sealing of hull and turret and installation of detachable equipment
Method of underwater movement	In 1st range
Means to maintain desired direction in underwater movement	Gyro direction indicator GPK-59 and radio communications
Time to install detachable items of underwater stream-crossing equipment	20 min
Time to dismount detachable items of underwater stream-crossing equipment and to stow them in traveling position	15 min
Time to prepare vehicle for firing after crossing a water barrier	1 to 2 min
Water discharge means	One bilge pump (capacity 100 l/min at back pressure of 4m of H_2O)
Mass of underwater stream-crossing equipment	70 kg
2.11.5. Earth-Moving Equipment	
Type	Built-in bulldozer
Moldboard width	2,140 mm
Mass of detachable part	200 kg
Time to dig out a tank shelter pit of (10-12) × (4.5-5.5) × (1.2-1.5) m:	
On sandy loam and sandy soil	12 to 15 min
On vegetable soil and clay	20 to 40 min
Time to change equipment from traveling to operating position	1 to 2 min
Time to change equipment from operating to traveling position	3 to 5 min
Total time of shelter making	Not more than 25 min
2.11.6. Equipment for Making Passages in Minefields	
Type	Tread blade-type mine exploder
Model	KMT-6

[a] It is permissible to use fuel grade DZ when changing from cold to hot season operation.

[b] Gasoline A-66 and A-72 are used whenever diesel fuel or fuel grade TC-1, T-1, and T-2 are not available. The ambient temperature in this case should not be below −30°C or above +25°C, and total operating hours must not exceed 100 hours.

This appendix is ~~Secret~~

Appendix B

Table 2